8291

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H02K 9/00

A1

(11) International Publication Number: WO 99/17429

(43) International Publication Date: 8 April 1999 (08.04.99)

(21) International Application Number: PCT/SE98/01737

(22) International Filing Date: 29 September 1998 (29.09.98)

(30) Priority Data:
9703551-3 30 September 1997 (30.09.97) SE

(71) Applicant (*for all designated States except US*): ASEA BROWN BOVERI AB [SE/SE]; S-721 83 Västerås (SE).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE). KYLANDER, Gunnar [SE/SE]; Stentorpsgatan 16 A, S-723 43 Västerås (SE).

(74) Agent: EMTEDAL, Artur; L.A. Groth & Co. KB, P.O. Box 6107, S-102 32 Stockholm (SE).

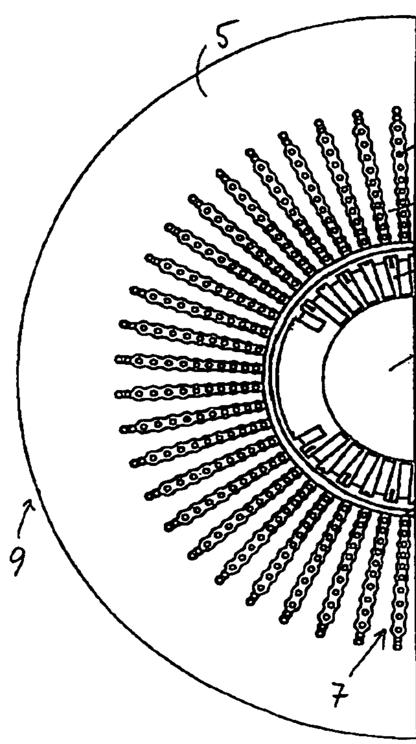
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Swedish).

(54) Title: DEVICE FOR A ROTATING ELECTRIC MACHINE

(57) Abstract

A device and a method for thermally insulating a rotating electric machine comprising a stator (1), wound with a high voltage cable (11), and a rotor (17), whereby the machine is provided with a thermal insulation (20, 60, 70, 90) in the air gap between the stator (1) and the rotor (17).



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

DEVICE FOR A ROTATING ELECTRIC MACHINE

Technical field

The present invention relates not only to a rotating electric machines for high voltage, for example synchronous machines, but also to double-fed machines, applications of asynchronous converter cascades, outer pole machines and synchronous flux machines and also alternating current machinery, which are mainly used as generators in a power plant for the generation of electric power. The invention relates more specifically to cooling within the air duct and the means of transporting the coolant through the cooling duct between the rotor and the stator in such machines.

Background art

Such machines have conventionally been designed for voltages in the range 15 - 30kV and 30 kV has normally been considered to be an upper limit. This means in the case of a generator that a generator must be connected to the power network via a transformer, which steps up the voltage to the level of the power network, i.e. in the range of 130 - 400 kV. The present invention is intended for use at high voltages, i.e. voltages that mainly exceed 10 kV. A typical operating range for a machine according to the present invention may be voltages from 36 kV up to 800 kV.

Rotating electric machines for high voltage, i.e. voltages exceeding 10kV and up to a maximum of 30-35kV are normally provided with a cooling system for forced cooling of the machine. Two different types of air-cooled systems exist for conventional cooling: radial cooling where the air passes through the hub and is conducted further through radial ducts in the rotor, and axial cooling where the air is blown into the pole gaps by axial fans.

Rotating electric machines for high voltage are normally constructed of a stator provided with slots, stator slots, in which the AC-windings or stator winding are located. The slots are normally rectangular or trapezoidal in shape. So-called stator teeth are formed between the slots. Each winding phase consists of a plurality of coil groups connected in series and each coil group consists of a plurality of coils connected in series. The different parts of the coil are designated as the coil side for the part which is placed within the stator and the end winding for that part which is on the

outside of the stator. A coil consists of one or more conductors brought together in height and/or width. Between each conductor there is a thin insulation, for example epoxy/glass fibre. The coil is electrically insulated from the slot by coil insulation, that is, insulation intended to withstand the rated voltage of the machine to ground. Various plastic materials, varnish and glass fibre materials may be used as insulating material. Usually, so-called mica tape is used, which is a mixture of mica and hard plastic material, especially produced to provide resistance to partial discharges, which can rapidly break down the electrical insulation. The insulation is applied to the coil by winding several layers of the mica tape around the coil. The insulation is impregnated and the coil side is thereafter painted with a graphite-based paint to improve the contact with the surrounding stator, which is connected to ground potential. The stator may be constructed of laminated, normal or oriented steel or another amorphous or powder based material. There are also machines in which the power windings are placed in the rotor and field windings in the stator.

Gas cooling of both the stator and the rotor is used frequently for the cooling of large alternating current machines. It is usual for the gas to be transported radially through the stator in cooling ducts, which are formed by radially placed spacers. The spacers, separating the laminated core of the stator into units of approximately 30 mm in axial length, are normally 6-mm high and 2 mm thick straight rectangular steel elements.

Gas circulation in the electric machine may be arranged according to different principles. A hydro-generator is a multi-pole generator, which is characterized by a large stator diameter and salient poles. The rotor in a hydro-generator may be designed having radial cooling ducts, so that the air is transported radially within both the rotor and the stator. It is also usual for the gas to be pressed axially into the air gap by fans on both ends of the machine, after which it turns 90° and to then depart radially through the stator ducts. A turbo-generator having few poles, i.e. 2 or 4 poles, is characterized by a substantially cylindrically formed rotor. The rotor conductors in the turbo-generator are frequently cooled by gas transported within the axial ducts, which are connected to the conductors. The heated gas is released into the air gap via the radial ducts, which are frequently concentrated towards the centre. The stator in the turbo-generator is divided up into different cooling chambers in

which the direction of the gas flow may change so that the cold air may be pressed down into the air gap in some chambers and warm air may escape from the air gap in other chambers. So-called reversed cooling is applied to some turbo machines, which means that the rotor fans suck gas from the air gap instead of pressing gas into the air gap. This is advantageous as the stator is cooled in this way by cool air instead of the warm rotor air. The rotor fan blades are then placed on top of the rotor retaining rings instead of being mounted axially behind the rotor retaining rings.

The cool air may consist of the surrounding air but at powers exceeding 1 MW, a closed cooling system with heat exchangers is often used. Hydrogen cooling is normally used in turbo generators and large synchronous condensers up to approximately 400 MW. This cooling method functions in a similar manner to air cooling with heat exchangers, but hydrogen gas is used instead of air as a coolant. The hydrogen gas has a better cooling capacity than air, but difficulties arise at seals and in monitoring leakage. Punched core disks being layered on top of each other in order to build up segments usually produce cooling ducts in the rotor.

Aim of the invention

The aim of the invention is to achieve a cooling system for a rotating electric machine for high voltage from 10 kV and up to the level of the voltage of the power network. It is intended that such a rotating electric machine should be connected directly to a power network without the use of an intermediate transformer. The new type of rotating electric machine has a number of features that make particular demands on the cooling system when compared to a conventional machine.

Summary of the invention

The aforementioned aim is achieved with the device, according to the invention, as defined in the characterizing part of the appended Claims.

By using high voltage insulated electric conductors, hereinafter called high voltage cables, with permanent insulation similar to that used in cables for transmitting electric power (e.g. XLPE cables) the voltage of the machine may be increased to such levels that it can be connected directly to the power network without intermediate transformers. The conventional transformer may thus be eliminated. This

concept requires that the slots in the stator, in which the high voltage cables are placed, be deeper than with conventional technique (thicker insulation as a result of higher voltage and more turns in the winding). This means that the distribution of losses differs from a conventional machine, which in turn creates new problems with respect to the cooling of the stator teeth.

The insulated conductor or high voltage cable used in the present invention is flexible and bendable and of the type described in more detail in WO 97/45919 and WO 97/45847. Additional descriptions of the insulated conductor or cable can be found in WO 97/45918, WO 97/45930 and WO 97/45931.

Thus, in a device according to the invention the windings are preferably of a kind similar to cables having solid, extruded insulation, of a type used presently for power distribution, such as XLPE cables or cables having EPR insulation. Such a cable comprises an inner conductor composed of one or more strands, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding the conductor and an outer semiconducting layer surrounding the insulating layer. Such cables are bendable, which is an important property in this respect since the technology for the device, according to the invention, is based primarily on a winding system in which the winding is formed from cables which are bent during assembly. The bending ability of an XLPE cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the designation bending ability is used to indicate that the winding is bendable down to the radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed so as to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this respect. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE cable, for example, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of polyethylene with both soot and metal particles mixed therein. Changes in the volume as a result of temperature fluctuations are completely absorbed as

changes in the radius of the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion of the layers in relation to the elasticity of these materials, radial expansion can take place without the loss of adhesion between the layers.

The material combinations stated above should be considered by way of example only. Other combinations fulfilling the specified conditions as well as the condition of being semiconducting, i.e. having a resistivity within the range of 10^{-1} - 10^{6} ohm-cm. e.g. 1 -500 ohm-cm or 10 - 200 ohm-cm naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentane (PMP), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed therein.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed therein or not, i.e. in the proportions required to achieve the conductivity necessary according to the invention. Thus, the insulating layer and the semiconducting layers have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber, butyl graft polyethylene, ethylene-acrylate-copolymers and ethylene-ethyl-acrylate copolymers may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as a base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case in the combination of the materials listed above.

The materials listed above have a relatively good elasticity, with an E-modulus of $E \leq 500$ MPa, preferably < 200 MPa . The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction by the elasticity so that no cracks or

other damage appear and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalise the potential along the layers respectively. The conductivity of the outer semiconducting layer is sufficiently large to contain the electrical field in the cable, but sufficiently small to not give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electric field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

The insulation of the winding in a machine, according to the present invention, consists of the same material as in high voltage solidly insulated cables, for example cross-linked polyethylene (XLPE). These materials do not have the same temperature durability compared to the insulation of conventional generators, which can manage approx. 130° - 155° C. Properties of XLPE already change at 70°C, an absolute upper temperature limit being 90°C. This means that a temperature rise in air-cooling of only 10 - 20 K is permissible as against the normal 40 - 60 K. This implies very large volumes of air which leads to large ventilation losses which in turn is a big disadvantage for a generator.

Furthermore, the stator teeth in a machine, according to the present invention, have a much more elongated form compared to a conventional machine. The long stator teeth are very sensitive to tangential magnetic forces, which act on the tooth surface facing the air gap. The laminations buckle between the spacers of the cooling ducts due to the pressure on the laminations in a traditionally gas cooled stator with radial cooling ducts. The buckling of the laminations leads to a to a largely deteriorating tangential stiffness of the laminations which would be an especially serious problem in the new type of electric machine. Bad tangential stiffness in such long stator teeth leads to a large risk of resonance and high amplitudes of oscillation, which in turn leads to a high sound level and breakdown in th long run.

It is therefore better to cool the new type of stator with water. The stator in this way may be produced homogeneously without being divided into steel packages separated by radial cooling ducts. The rotor may be completely conventional which implies that it is normally gas cooled. The problem arising then is that the heated gas from the rotor, which may exceed 110°C, heats the surface of the stator facing the air gap to such an extent that the temperature sensitive stator winding is at risk of being overheated. This is especially a problem regarding the turbo-generator.

The problem for turbo-generators of the new type is traceable to the fact that the coefficient of heat transfer is very high in the air gap, which gives rise to a large heat flow into the stator teeth. Besides, the electromagnetic losses in the stator teeth are greatest close to the air gap since the stator teeth taper towards the air gap, which implies an increasing magnetic flux density. The heat is difficult to lead away without getting a considerable temperature gradient as a result of the stator teeth being so long, producing a relatively high thermal resistance in the radial direction. It is also difficult to place enough cooling pipes where the stator teeth are at their most narrow. The losses in the cable lying closest to the air gap are furthermore greater than cables lying elsewhere as a result of the eddy currents, which arise in the copper conductors as a consequence of the slot leakage flux.

These problems may be solved if a thermal insulation in the form of a thermally insulating cylinder is arranged in the air gap between the rotor and the stator. The air gap hereby indicates the radial distance between the inner surface of the stator core and the outer surface of the rotor core. The cylinder will be solidly connected to the stator in most embodiments and protect the surface of the stator from being heated. The cylinder in a possible embodiment is furthermore provided with cooling pipes in order to provide extra cooling of the stator. The length of the cylinder does not need to correspond to the length of the stator, but may be either shorter or longer.

A normal embodiment of the cooling ducts in the rotor entails that the hot air flows axially through the internal rotor ducts by means of rotor fans and is released into the air gap, which is approximately in the middle of the axial length of the machine. The rotor air is then normally led out through the radial stator ducts. If this solution is to be applied then there must naturally be some stator ducts even though

the stator is water-cooled. The cylinder is then manufactured into parts or into plated holes, so that the stator ducts are not covered. Thermal insulation, in this case, should be applied over the uncovered stator winding in the radial cooling ducts, and also over the stator laminations which are exposed to the warm gas. The total axially extended length of the cylinder can be made shorter than the axial length of the stator since the warm rotor air is concentrated towards the central parts of the air gap.

The air gap insulation need not necessarily be constructed of a cylinder but can consist of a cast compound or a plurality of axial insulation plates, which are glued to the stator.

If the rotor fans are bent to the other direction then the warm gas may be sucked out through the air gap, so-called reversed cooling. The advantage with this is that no central ducts are needed in the stator, which create problems with the buckling of plates and thermal insulation. It is noteworthy that the gas circulation does not then correspond to the known type of reversed cooling for turbo generators since no stator ducts exist. This results in that the insulated cylinders should be longer than the stator since also the coil ends are to be protected from the warm gas.

<u>Brief description of the drawings</u>

The invention will be described in more detail in the following with reference to the accompanying drawings:

Figure 1 shows a partial schematic view in a diametric section through a stator of a rotating electric machine.

Figure 2 shows a cross sectional view of a high voltage cable according to the present invention.

Figure 3 shows schematically a sector of a rotating electric machine.

Figure 4 shows schematically a first embodiment according to the present invention.

Figure 5a shows schematically a second embodiment according to the present invention.

Figure 5b shows schematically a third embodiment according to the present invention.

Figure 6	shows a section through a first embodiment of a cylinder according to any of the embodiments shown in Figures 4, 5a or 5b.
Figure 7	shows a section through a second embodiment of the cylinder according to any one of the embodiments shown in Figures 4, 5a, or 5b.
Figure 8	shows a section through a third embodiment of a cylinder according to any one of the embodiments shown in Figures 4, 5a or 5b.
Figure 9	shows a fourth embodiment of a cylinder according to any one of the embodiments shown in Figures 4, 5a, or 5b.
Figure 10	shows a section through a fifth embodiment of a cylinder according to any one of the embodiments shown in Figures 4, 5a or 5b.
Figure 11	shows an end view of an embodiment according to Figure 10.

Description of the invention

Figure 1 shows an electric machine provided with a rotor 17 and a stator 1. The main parts of the stator 1 consist of a stator frame 2 and a stator core 3. As shown in the Figure, the stator winding forms a so-called coil ends package 8 at both sides of the stator 1.

The stator frame 2 in larger conventional machines is often designed as a welded steel construction. The stator core 3, also referred to as a laminated core, in larger machines is normally designed of 0,50 mm so-called steel laminations which are assembled into packages having an axial length of approximately 50 mm and which are separated from each other by an intermediate space constituting ventilation ducts of approximately 5 mm. However, the ventilation ducts are disposed of in a machine according to the present invention. The construction of each packet of stampings in large machines is performed by putting suitably large punched sheet segments 9 together to form a first layer whereby each subsequent layer is overlapped for the construction of an entirely disk shaped part of the stator core 3.

Figure 2 shows a cross-sectional view of a high voltage cable 11 according to the present invention. The high voltage cable 11 comprises a plurality of strands 12 having a circular cross section of for example copper (Cu). These strands 12 are arranged in the centre of the high voltage cable 11. A first semiconducting layer 13 is arranged around the strands 12. Around the first semiconducting layer 13 there is ar-

ranged an insulation layer 14, of for example XLPE insulation. Around the insulation layer 14 there is arranged a second semiconducting layer 15. The concept of a high voltage cable in the present application does thus not comprise the outer shield, which normally surrounds such a cable during energy distribution. The three layers are constructed such that they adhere to each other even when the cable is bent as shown in the detail of the Figure referring to the insulated conductor or cable. The shown cable is flexible and this property is retained during the length of its life.

Figure 3 shows schematically a sector of the machine, which has a sheet segment 9 of the stator 1 and a rotor pole 16 on the rotor 17 of the machine. It is further evident that the stator winding 6 is arranged in the space 7, in the shape of a bicycle chain, between each stator tooth 4. The Figure also shows that the stator core comprises stator teeth 4 and a stator yoke, which constitutes the outer yoke section 5. The stator furthermore consists of one of the stator windings 6, arranged in the high voltage cable, which is placed in a space 7 in the shape of a bicycle chain formed between each separate stator tooth 4. This conductor only distinguishes the stator winding 6 in the Figure. It is furthermore evident in the Figure that the high voltage cable is stepped in several dimensions depending on its radial position in the stator 1. Each one of the stator teeth 4 stretches inwardly from the outer yoke section 5. Besides, a thermally insulating cylinder 20, connected to the stator, is located in the air gap between the stator 1 and the rotor 17.

Figure 4 shows an axial section of a first embodiment of the gas cooling of a rotor 17 belonging to a machine which is provided with a liquid-cooled stator, for example a water-cooled stator 1. Cooling gas hereby flows into the air gap 22 from both sides of the rotor and then through at least one radial duct 24 in the stator 1. A thermally insulating barrier in the form of a cylinder 20 is connected to the stator and located in the air gap between the stator and the rotor in order to insulate the stator windings which are situated in the stator. The cylinder 20 is designed with a gas draining means 26 in the form of a hole, slits or intervals between the partial cylinders in order to release cooling gas radially through the cylinder 20 and then out through the duct 24. Besides, the cylinder 20 may be divided into several partial cylinders 20', 20" whereby the cylinder allows for the radial release of cooling gas be-

tween these partial cylind rs 20', 20". Likewise, the duct 24 is thermally insulated in order to protect the stator winding against the hot cooling gas.

Figure 5a shows an axial section of a second embodiment of the gas cooling of a rotor 17 belonging to a machine which is provided with a liquid-cooled stator 1. Cooling gas flows hereby axially in through the rotor and then flows radially out through the rotor and into the air gap 22. The cooling medium is then sucked axially out of the air gap, from both sides of the rotor, and then out past the coil end sections 28 on either side of the stator 1. The stator even in this embodiment of a gas-cooled rotor has also been provided with a thermally insulating cylinder 20, but the cylinder 20 is devoid of gas draining means due to another gas-flowing embodiment and is thus designed homogeneously and hereby sealed in the radial direction without a possibility for gas to flow radially through the cylinder walls.

Figure 5b shows an embodiment corresponding to 5a differing only in this third embodiment in that the cooling gas is arranged to flow axially through the entire rotor 17 and the air gap 22 of the entire machine, i.e. in at the one side and out at the other.

The cylinder 20 is designed according to a plurality of embodiments in order to act as an insulating barrier either in the form of gas cooling according to Figure 4 or as gas cooling according to Figure 5.

In a first embodiment of the cylinder 20, according to Figure 6, the cylinder 20 is designed as a homogeneous pipe section 60 manufactured of a material with a low thermal conductivity. Armoured glass fibre epoxy or other polymer material is suitable material for the thermally insulated cylinder. This has a thermal conductivity of 0.3 W/mK.

In another embodiment of the cylinder 20, according to Figure 7, the cylinder 20 is designed of spirally wound cooling pipes 70. The cooling pipes 70 have hereby been designed with a rectangular cross section in order to maintain the large flow area in relation to the radial extension. The cylinder, according to this embodiment, may also be designed with cooling pipes having a circular cross section, which are wound spirally around an extruder core leaving a distance between each winding turn after which the pipes are "flattened" in order that the pipe obtains a homogeneous pipe-formed appearance.

Figure 8 shows a third embodiment of the cylinder 20, which is designed as a spiral formed twin pipe 80 being a combination of the embodiments according to Figure 6 and Figure 7, i.e. a homogeneous pipe section 60 surrounded by a cooling pipe 70.

Figure 9 shows a fourth embodiment of the cylinder, which is formed as an axial cooling pipe cylinder 90. The cooling pipe 70 hereby runs parallel to the stator teeth 4 in the air gap 22.

Figure 10 shows a fifth embodiment of the cylinder formed as an axially wound twin pipe 20 having a homogeneous pipe section 60, which is wound by an axially running cooling pipe 70 forming a pipe on the outside.

Figure 11 shows within a section the circularly formed cooling pipes 70 which are wound around the homogeneous pipe section 60 forming in this way the axially wound twin pipe 100.

Cooling pipes, in all the embodiments in which the cylinders comprise cooling pipes, may be designed having circular, elliptical or rectangular cross section, either in the form of a homogeneous cylinder or having the possibility of radially letting cooling gas through.

The cylinder 20 is suitably located concentrically at a small distance from the inner surface of the stator so as to improve the insulation further in the air gap 22. The small void between the stator and the cylinder may, but does not necessarily need to be filled with insulation material such as for example glass fibre wool. The cylinder provides mechanical strength then whereas the glass fibre wool forms the primary insulation material. The cylinder 20 is not to be too thick, since a problem arises when inserting the rotor with its retaining rings into the stator. The cylinder and the void may each have a suitable thickness value of approximately 5 mm. Different possibilities, such as using spacers to wedge the cylinder 20 concentrically into the air gap 22, may be exploited in order to fasten the cylinder 20 in the stator.

CLAIMS

1. A rotating electric machine comprising a rotor (17), **characterized** in that the machine further comprises a stator (1) wound by a high voltage cable (11), having an inner conductor composed of one or more strands (12), the conductor surrounded by an inner semiconducting layer (13), the semiconducting layer surrounded by a solid insulation layer (14) and the insulation layer (14) surrounded by an outer semiconducting layer (15) and that the machine is provided with a thermal insulation (20, 60, 70, 90) in the air gap between the stator (1) and the rotor (17).

2. A machine according to claim 1, **characterized** in that the stator (1) is liquid-cooled and that the rotor (17) is gas-cooled.

3. A machine according to any one of claims 1 - 2, **characterized** in that the rotor cooling media are arranged to flow axially inwards, from each of the rotor ends, towards the centre of the rotor (17) by flowing both through the air gap and through the centre of the rotor and to then flow outwards through at least one radial duct (24) in the stator (1) via gas draining means (26) in the thermal insulation (20, 60, 70, 90).

4. A machine according to any one of claims 1 - 2, **characterized** in that the rotor cooling media are arranged to flow axially inwards, from each of the rotor ends, through the rotor (17) towards the centre of the rotor (17) and radially outwards into the air gap (22) and to then flow out through the air gap (22) in both directions.

5. A machine according to any one of claims 1 - 2, **characterized** in that the rotor cooling media are arranged to flow axially inwards from the one rotor end through the entire rotor (17), both through the air gap and through the centre of the rotor and then out through the other end of the rotor.

6. A machine according to any one of claims 1 - 5, **characterized** in that one cylinder (20) is located in the air gap between the stator (1) and the rotor (17) in order to function as a thermally insulating barrier between the stator and the rotor.

7. A machine according to claim 6, **characterized** in that the cylinder (20) is connected to the stator (1).

8. A machine according to any one of claims 6 - 7, **characterized** in that the cylinder (20) is designed as spirally wound cooling pipes (70)

9. A machine according to any one of claims 6 - 7, **characterized** in that the cylinder (20) is designed as a cooling pipe cylinder (90) having axially running cooling pipes (70).

10. A machine according to any one of claims 6 - 7, **characterized** in that the cylinder (20) is designed as a pipe section (60).

11. A machine according to any one of claims 8 - 9, **characterized** in that the cooling pipe (70) is mounted on the outside of a pipe section (60).

12. A machine according to any one of claims 8 - 9 or 11, **characterized** in that the cooling pipe (70) displays a rectangular cross section.

13. A machine according to any one of claims 1 - 12, **characterized** in that the cylinder (20) is provided with gas draining means (26) in order to enable the radial release of cooling gas through the stator (1).

14. A machine according to any one of claims 1 - 12, **characterized** in that the cylinder is divided into a plurality of partial cylinders (20', 20") in order to enable the radial release of cooling gas through the stator (1).

15. A machine according to any one of claims 1 - 12, **characterized** in that the entire cylinder (20) is sealed in the radial direction in order to prevent cooling gas from penetrating through the cylinders and to heat the stator windings (6) up.

16. A machine according to any one of claims 10 - 15, **charact rized** in that the pipe section (60) is manufactured of a material having a low coefficient of thermal conductivity.

17. A machine according to claim 16, **characterized** in that the pipe section (60) is manufactured of a polymer material.

18. A machine according to any one of claims 6 - 17, **characterized** in that the cylinder (20) is concentrically arranged with a void towards the inner surface of the stator (1) and that the void is filled with insulation material, for example glass fibre wool.

19. A machine according to any one of claims 1 - 18, **characterized** in that the layers (13, 14, 15,) are arranged to adhere to each other even when the insulating conductor or cable is bent.

20. A method of thermally insulating a rotating electric machine, **characterized** in that the machine comprises a liquid-cooled stator (1) wound by a high voltage cable (11), having an inner conductor composed of one or more strands (12), the conductor surrounded by an inner semiconducting layer (13), the semiconducting layer surrounded by a solid insulation layer (14) and the insulation layer (14) surrounded by an outer semiconducting layer (15) which stator is provided with an outer yoke section (5), from which the stator teeth (4) stretch inwardly, and a gas-cooled rotor (17) and that the thermal insulation between the stator (1) and the rotor (17) is achieved by inserting a thermal insulation into the air gap between the stator (1) and the rotor.

21. A method according to claim 20, **characterized** in that a cylinder (20) is placed into the air gap between the stator (1) and the rotor (17) and connected to the stator (1) in order to function as a thermally insulating barrier between the stator and the rotor.

22. A method according to claim 21, **charact rized** in that th cylinder (20) also prevents gas flow through the coil ends on one or both sides of the stator (1).

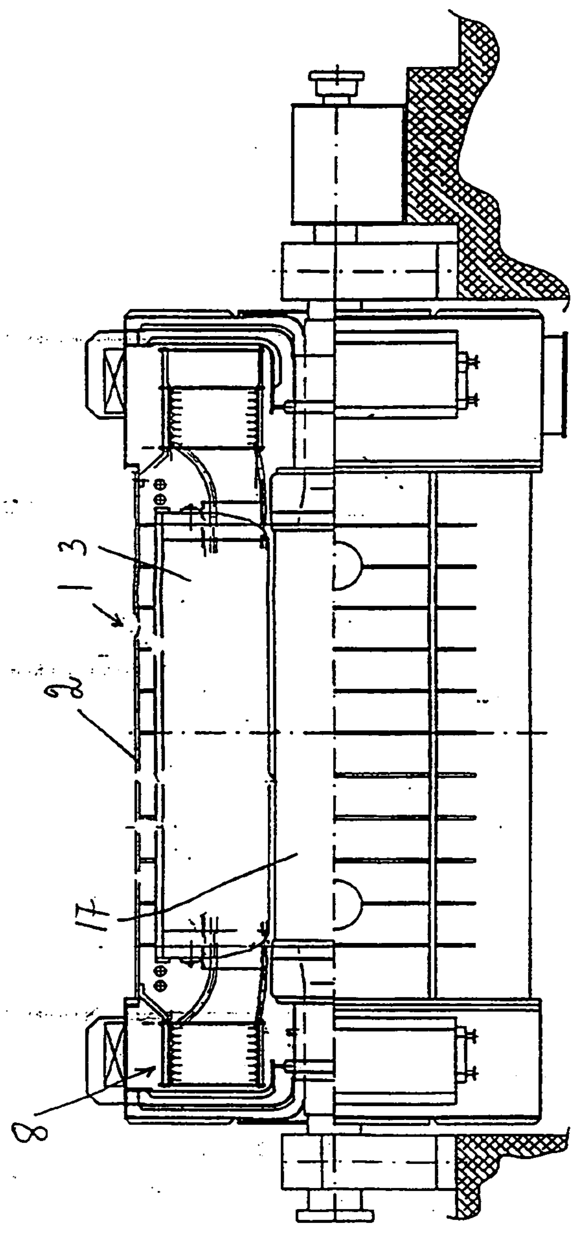
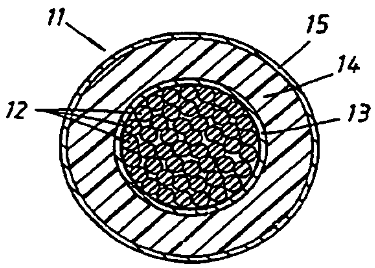


Fig. 1

Fig. 2



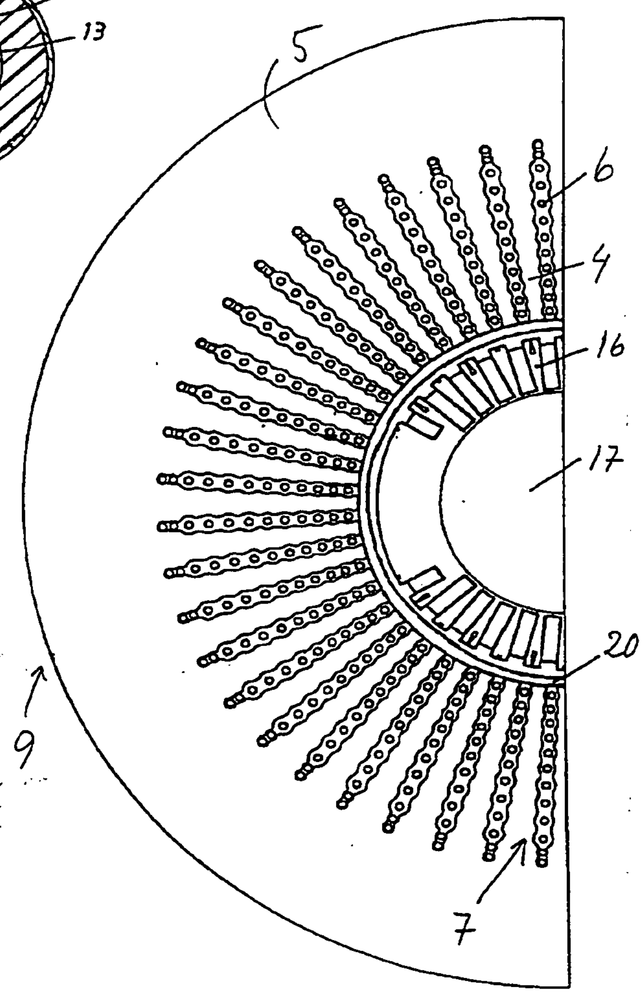


Fig. 3

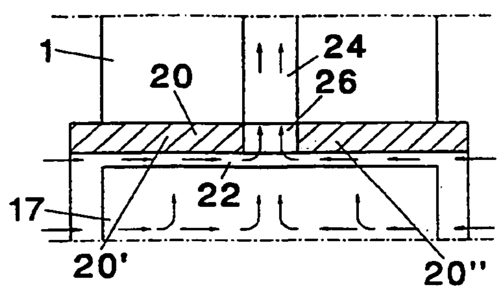


Fig 4

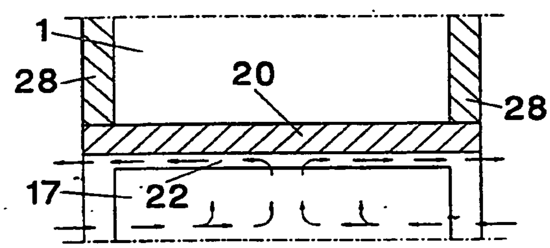


Fig 5a

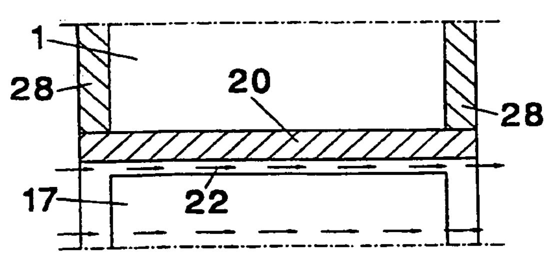


Fig 5b

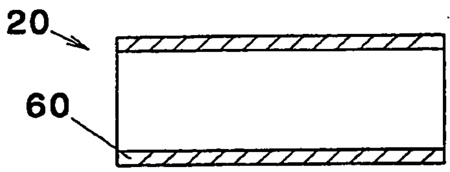


Fig 6

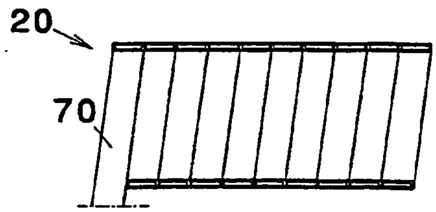


Fig 7

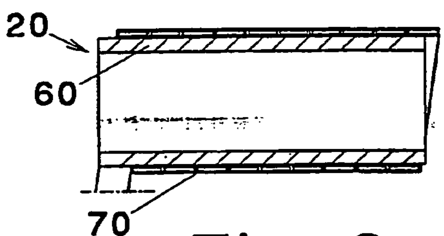


Fig 8

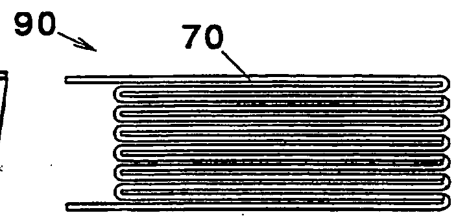


Fig 9

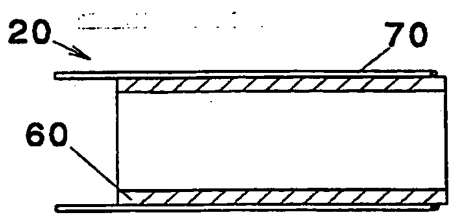


Fig 10

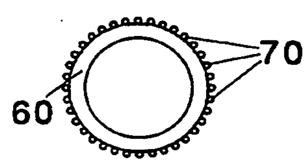


Fig 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01737

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02K 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3727085 A (P.B.GOETZ ET AL), 10 April 1973 (10.04.73), see the whole document --	1,6,20
Y	US 4785138 A (O.BREITENBACH), 15 November 1988 (15.11.88), see the whole document --	1,6,20
A	US 5036165 A (R.ELTON ET AL), 30 July 1991 (30.07.91), abstract --	1-22
A	US 3809933 A (H.SUGAWARA ET AL), 7 May 1974 (07.05.74), abstract --	1-22

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 1998	03 -12- 1998
Name and mailing address of the ISA/ Swedish Patent Offic Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01737

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4239999 A (A.A. VINOKUROV ET AL), 16 December 1980 (16.12.80), abstract -- --------	1-22

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/11/98

International application No.
PCT/SE 98/01737

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3727085 A	10/04/73	NONE	
US 4785138 A	15/11/88	DE 3543106 A,C	11/06/87
US 5036165 A	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
		US 4853565 A	01/08/89
US 3809933 A	07/05/74	JP 48031403 A	25/04/73
US 4239999 A	16/12/80	DE 2753461 A,B,C	01/06/78
		FR 2372535 A,B	23/06/78
		GB 1547060 A	06/06/79
		JP 53086415 A	29/07/78
		JP 61003175 B	30/01/86